Physics 12
January 1996 Provincial Examination

ANSWER KEY / SCORING GUIDE

TOPICS:
1. Kinematics and Dynamics
2. Energy and Momentum
3. Equilibrium
4. Circular Motion and Gravitation
5. Electrostatics and Circuitry
6. Electromagnetism
7. Quantum Mechanics
8. Fluid Theory
9. AC Circuitry and Electronics

PART A: Multiple Choice

Q	C	T	K	S	CGR	Q	C	T	K	S	CGR
1.	K	1	C	2	I C3	16.	U	5	A	2	VI A2
2.	U	1	D	2	I A1	17.	U	5	B	2	VI A6
3.	K	1	A	2	II B5	18.	U	5	C	2	VI A5, 7
4.	U	1	B	2	I C 6	19.	U	5	C	2	VI B2, 3
5.	H	1	C	2	II B 6	20.	K	5	A	2	VII A8
6.	K	2	A	2	III A3	21.	U	5	B	2	VII A2
7.	U	2	A	2	III A7, 6	22.	U	5	C	2	VII A6, 7
8.	U	3	C	2	IV B8	23.	H	5	B	2	VII A10, 11
9.	H	3	B	2	IV B6	24.	K	6	D	2	VIII A2
10.	K	4	B	2	V A1	25.	U	6	A	2	VIII A3
11.	U	4	C	2	V A4	26.	U	6	A	2	VIII A6
12.	U	4	C	2	V B3	27.	K	6	A	2	VIII B1
13.	U	4	D	2	V B15	28.	K	6	B	2	VIII B6
14.	H	4	C	2	V A6, II B6, B3	29.	U	6	C	2	VIII B7
15.	K	5	B	2	VI A7	30.	U	6	B	2	VIII B13, 14

PART B: Written Response

Q	B	C	T	S	CGR
1.	1	U	1	7	I B 10
2.	2	U	2	7	III C 8, 9
3.	3	U	3	7	IV A 3
4.	4	U	4	7	II A 5, V B 6
5.	5	U	5	7	VII A 6, 7, 8
6.	6	U/H	6	9	VIII B 11, 10
7.	7	H	2	4	III A 1, 2

PART C: Elected Topics

Only **one** of the following sections will be chosen. Score only **one** set of boxes: (8, 9, 10) **or** (11, 12, 13) **or** (14, 15, 16). Maximum possible score for Part C is 12.

	Q	B	C	T	S	CGR
Section I	1.	8	U	7	3	II B 6
	2.	9	U	7	4	II A 9, 14
	3.	10	U	7	5	II A 6, 14, B 5

or

	Q	B	C	T	S	CGR
Section II	1.	11	U	8	3	III B 12
	2.	12	U	8	4	III A 13
	3.	13	U	8	5	III A 2, 9

or

	Q	B	C	T	S	CGR
Section III	1.	14	U	9	3	I A 3
	2.	15	U	9	4	I D 4, 5
	3.	16	U	9	5	I C 2, 7

Multiple Choice = 60 (30 questions)

Written Response = 60 (10 questions)

Total = 120 marks

LEGEND:

Q = Question Number   **C** = Cognitive Level   **T** = Topic
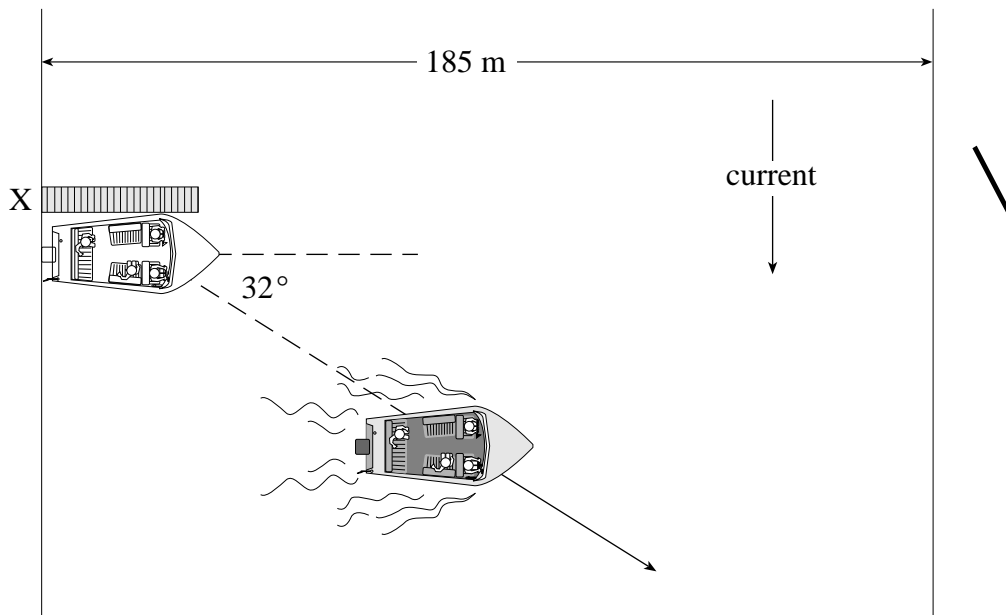
K = Keyed Response   **S** = Score   **CGR** = Curriculum Guide Reference
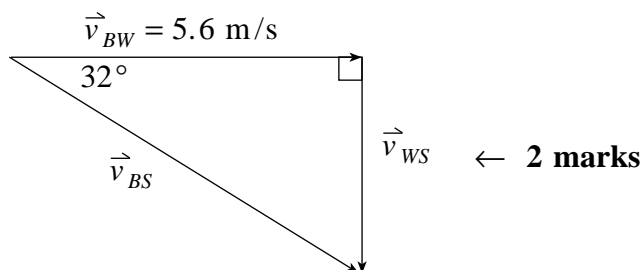
B = Score Box Number

1. A boat which can travel at 5.6 m/s in still water heads due east across a river from a dock at **X**. The boat's resultant path is 32° south of east.

   a) What is the speed of the current? **(5 marks)**

$$\tan 32° = \frac{v_{WS}}{5.6 \text{ m/s}}$$

$$v_{WS} = 5.6 \tan 32°$$

$$v_{WS} = 3.5 \text{ m/s} \qquad \leftarrow \textbf{3 marks}$$

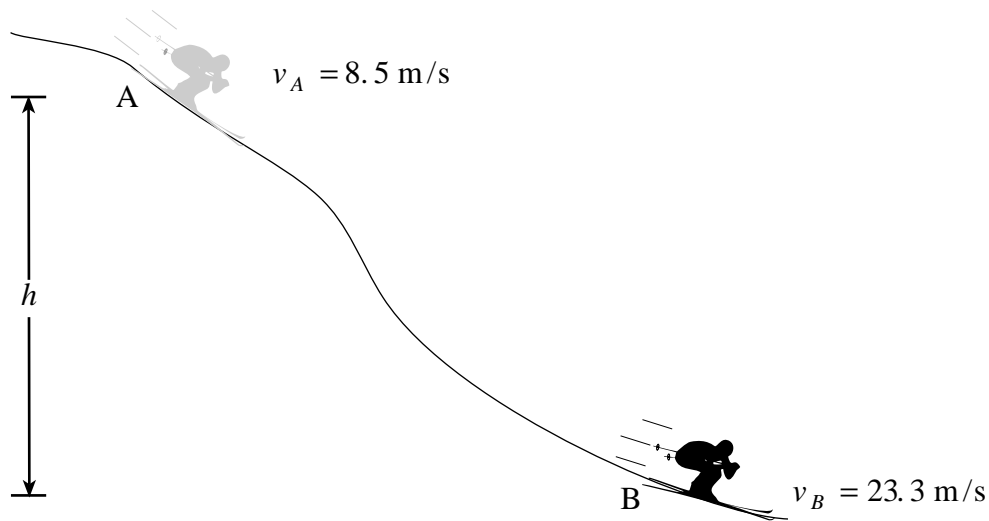   b) How long will it take the boat to reach the far shore if the river is 185 m wide? **(2 marks)**

$$v_E = \frac{d_E}{t} \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$5.6 = \frac{185}{t}$$

$$t = \frac{185}{5.6} \qquad \leftarrow \textbf{1 mark}$$

$$t = 33 \text{ s} \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

2. As a 62 kg skier descends from **A** to **B** her velocity increases from 8.5 m/s to 23.3 m/s. Friction between **A** and **B** generates 8 700 J of heat energy. Through what vertical height, **h**, did the skier descend? **(7 marks)**

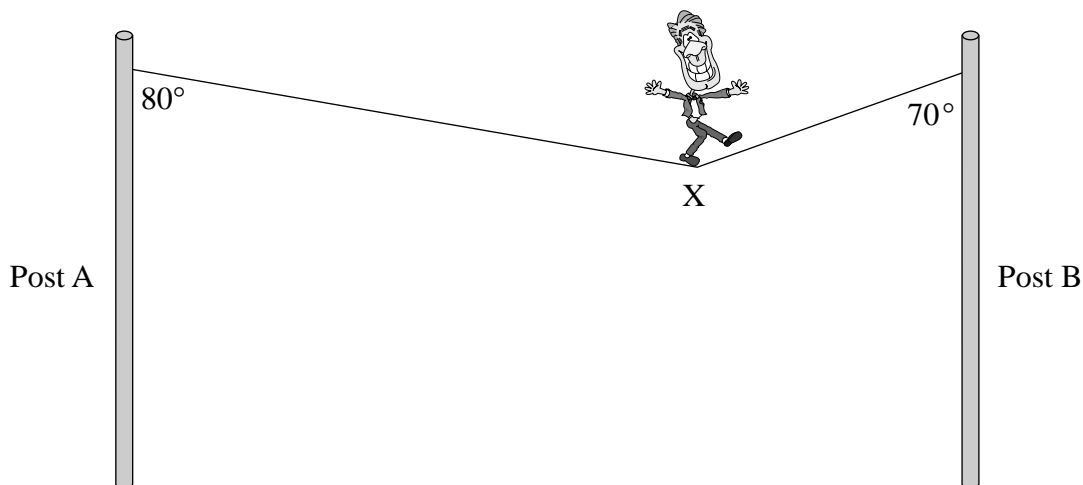$$E_A = E_B \qquad\qquad \leftarrow \text{ 1 mark}$$

$$E_p + E_k = E_p{'} + E_k{'} + E_H{'} \qquad\qquad \leftarrow \text{ 2 marks}$$

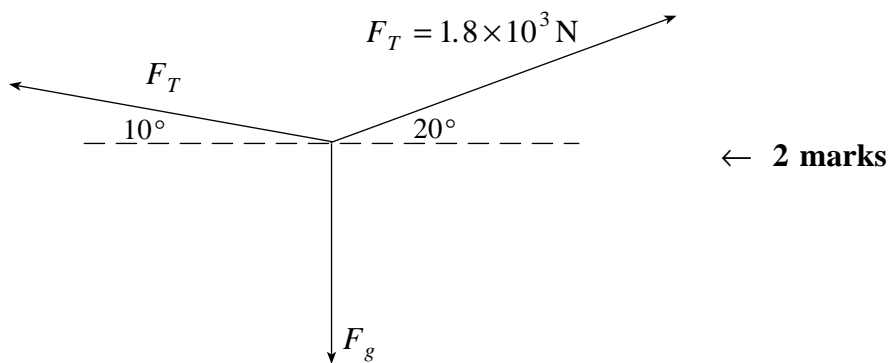$$mgh = \frac{1}{2} m v_B{}^2 - \frac{1}{2} m v_A{}^2 + \Delta E_H \qquad\qquad \leftarrow \text{ 2 marks}$$

$$= \frac{\frac{1}{2}(62)\left(23.3^2 - 8.5^2\right) + 8\ 700}{62(9.8)} \qquad\qquad \leftarrow \text{ 1 mark}$$

$$h = 38 \text{ m} \qquad\qquad \leftarrow \text{ 1 mark}$$

3. A circus performer walks across a wire stretched between two vertical posts. When the performer stands at position **X** as shown below, the tension in the short length of wire attached to post **B** is 1.8×10^3 N.

a) Draw and label a free body diagram showing the forces acting at position **X**. **(2 marks)**

$\leftarrow$ **2 marks**

b) What is the mass of the circus performer? **(5 marks)**

$$\sum F_X = 0 \quad F_T \cos 10° = 1.8 \times 10^3 (\cos 20°) \qquad \leftarrow \textbf{2 marks}$$

$$F_T = 1.72 \times 10^3 \text{ N}$$

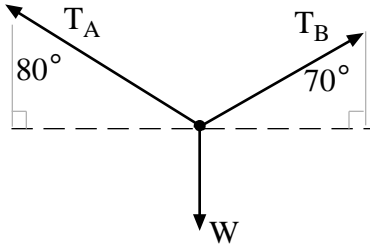$$\sum F_y = 0 \quad 1.72 \times 10^3 \sin 10° + 1.8 \times 10^3 \sin 20° = F_g$$

$$F_g = 914 \text{ N} \qquad \leftarrow \textbf{2 marks}$$

$$F_g = mg$$

$$m = \frac{914}{9.8} = 93 \text{ kg} \qquad \leftarrow \textbf{1 mark}$$

Alternate Response for Question 3.

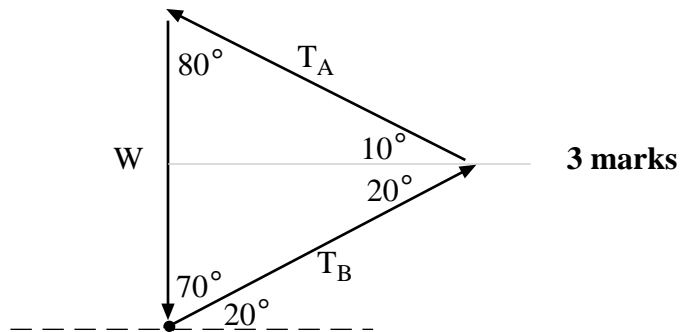a)   Draw and label a free body diagram showing the forces acting at position **X**.   **(2 marks)**

T_A T_B

$80°$ $70°$

W

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b)   What is the mass of the circus performer?   **(5 marks)**

In equilibrium

$0 = T_A + T_B + W$

$T_B = 1\,800$ N

$80°$ T_A

W $10°$ **3 marks**
   $20°$

$70°$ T_B
   $20°$

$$\frac{\sin 30°}{W} = \frac{\sin 80°}{1\,800 \text{ N}}$$ ←**1 mark**

$$W = \left(\frac{\sin 30°}{\sin 80°}\right) 1\,800 \text{ N}$$

$$W = \left(\frac{0.5}{0.98}\right) 1\,800 \text{ N}$$

$W = 913.8$ N   ← $\frac{1}{2}$ **mark**

$W = 914$ N

$$M = \frac{914 \text{ N}}{9.8}$$ ← $\frac{1}{2}$ **mark**

$M = 93$ kg

4. An astronaut stands on the surface of a planet of radius 2.6×10^6 m. An object dropped from the astronaut's hand accelerates at 3.2 m/s^2.

a) What is the mass of this planet? **(5 marks)**

$$F_{net} = F_G$$

$$ma = \frac{Gm_1m_2}{r^2} \qquad \leftarrow \textbf{1 mark}$$

$$a = \frac{Gm}{r^2} \qquad \leftarrow \textbf{1 mark}$$

$$m = \frac{ar^2}{G} \qquad \leftarrow \textbf{1 mark}$$

$$m = \frac{(3.2)(2.6 \times 10^6)^2}{6.67 \times 10^{-11}} \qquad \leftarrow \textbf{1 mark}$$

$$m = 3.2 \times 10^{23} \text{ kg} \qquad \leftarrow \textbf{1 mark}$$

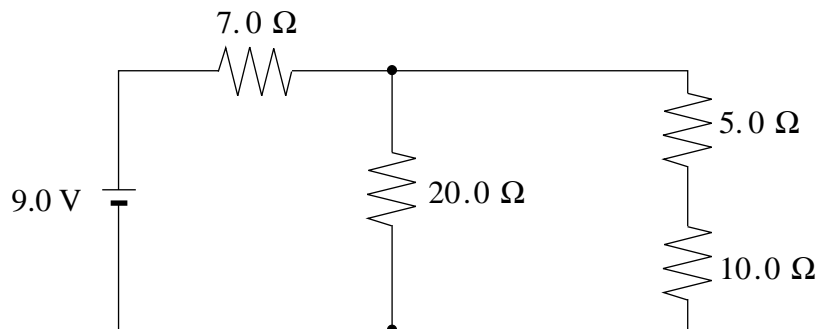b) What is the force of gravity on an 18 kg mass located on the surface of this planet? **(2 marks)**

$$F = ma \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$= (18)(3.2) \qquad \leftarrow \textbf{1 mark}$$

$$= 58 \text{ N} \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

5. In the circuit shown below, determine the current through the 5.0 Ω resistor. **(7 marks)**

$$\frac{1}{R_{||}} = \frac{1}{20} + \frac{1}{15}$$

$R_{||} = 8.57\ \Omega$ ← **2 marks**

$R_T = R_7 + R_{\text{parallel}}$

$R_T = 15.57\ \Omega$ ← **1 mark**

$\therefore I_T = \dfrac{V_T}{R_T} = \dfrac{9.0\ \text{V}}{15.57\ \Omega} = 0.578\ \text{A}$ ← **1 mark**

$\therefore V_7 = IR_7 = 0.578(7) = 4.05\ \text{V}$ ← **1 mark**

$\therefore$ net V across parallel branch 4.95 V   ← **1 mark**

so $I = \dfrac{V}{R} = \dfrac{4.95}{15} = 0.33\ \text{A}$ ← **1 mark**

6. a) A 16.0 V power supply is used to run a dc motor. When the motor is jammed so that it cannot turn, it draws a current of 12.0 A. What is the back or counter emf when the motor runs freely, drawing a current of 2.50 A? **(5 marks)**

$$R = \frac{V}{I}$$

$$= \frac{16 \text{ V}}{12 \text{ A}} \qquad \leftarrow \textbf{ 2 marks}$$

$$= 1.\bar{3} \, \Omega$$

$$V_b = V_{app} - IR$$

$$= 16 \text{ V} - \left(1.\bar{3} \, \Omega \times 2.5 \text{ A}\right) \qquad \leftarrow \textbf{ 2}\tfrac{1}{2} \textbf{ marks}$$

$$= 12.7 \text{ V} \qquad\qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

b) Using principles of physics, explain why the motor draws a much higher current when jammed than when running freely. **(4 marks)**

When running freely, the motor acts as a generator producing an emf that opposes the applied voltage **(1 mark)**. When the motor is jammed **(1 mark)**, there is no back emf **(1 mark)** and thus no opposition to the current **(1 mark)**, which is therefore larger.

7. Two students throw identical tennis balls towards a building at the same speed. One ball strikes the wall, bouncing back at half its original speed. The other ball smashes a window and continues in the same direction at half its original speed. Did the two tennis balls experience the same impulse when in contact with the wall and the window? Justify your answer using principles of physics.

(4 marks)

- The two tennis balls experienced **different** impulses. **1 mark**

- Impulse, or change in momentum, is a **vector** quantity. The ball which bounced from the wall sustained an impulse given by: $m \Delta v = m\left(-\frac{1}{2}v - v\right) = -\frac{3}{2}mv$. (The negative sign indicates the direction of the impulse.)

- The ball which smashed the window experienced an impulse given by: $m \Delta v = m\left(\frac{1}{2}v - v\right) = -\frac{1}{2}mv$.

- Therefore, the balls experienced different impulses. **3 marks**

PART C: ELECTED TOPICS

SECTION I: Quantum Mechanics

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1. The electron in a singly-ionized helium atom (2 protons and 2 neutrons) has $-2.18\ e$V of energy. What is the quantum number for this energy state? **(3 marks)**

$$E_n = -13.6\frac{z^2}{n^2}\,e\text{V} \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

$$-2.18\ e\text{V} = \frac{-13.6(2)^2}{n^2}\,e\text{V} \qquad \leftarrow 1\tfrac{1}{2}\ \textbf{marks}$$

$$n = 5 \qquad\qquad \leftarrow \textbf{1 mark}$$

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2. Incident photons strike a surface with a work function of $2.2\ e$V. The maximum kinetic energy of the emitted electrons is 8.0×10^{-19} J. What is the wavelength of the incident photons? **(4 marks)**

$$KE_{\text{max}} = hf - w_0 \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

$$\frac{8.0\times10^{-19}}{1.6\times10^{-19}} = \frac{hc}{\lambda} - 2.2\ e\text{V} \qquad \leftarrow \textbf{2 marks} \qquad \leftarrow \text{Energy conversion } \textbf{1 mark;}\ \frac{hc}{\lambda}\ \textbf{1 mark}$$

$$\left. \begin{aligned} 7.2\ e\text{V} &= \frac{1\ 242}{\lambda}\,e\text{V}\cdot s \\[4pt] \lambda &= 173\ \text{nm} \end{aligned} \right\} \qquad \leftarrow 1\tfrac{1}{2}\ \textbf{marks} \qquad \leftarrow \text{alg } \textbf{1 mark;}\ \text{answer } \tfrac{1}{2}\ \textbf{mark}$$

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3. What is the de Broglie wavelength of a proton with a kinetic energy of $5\ 000\ e$V? **(5 marks)**

$$KE = 5\ 000\ e\text{V} = 5\ 000\left(1.6\times10^{-19}\right)\text{J} = 8.0\times10^{-16}\,\text{J} \quad \leftarrow \textbf{1 mark}$$

$$\frac{1}{2}mv^2 = 8.0\times10^{-16}\,\text{J} \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

$$\left. \begin{aligned} v &= \sqrt{\frac{2\left(8.0\times10^{-16}\right)}{1.67\times10^{-27}}} \\[4pt] v &= 9.79\times10^5\ \text{m/s} \end{aligned} \right\} \qquad \leftarrow \ \textbf{1 mark}$$

$$\lambda = \frac{h}{p} = \frac{h}{mv} \qquad\qquad \leftarrow \textbf{1 mark}$$

$$= \frac{6.63\times10^{-34}\,\text{J}\cdot\text{s}}{\left(1.67\times10^{-27}\right)\left(9.79\times10^5\right)} \qquad \leftarrow \textbf{1 mark}$$

$$\lambda = 4.1\times10^{-13}\ \text{m} \qquad\qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

END OF SECTION I: Quantum Mechanics

SECTION II: Fluid Theory

1. At what temperature is the average kinetic energy of an oxygen molecule 6.40×10^{-21} J? **(3 marks)**

$$E_k = \frac{3}{2}kT \qquad \leftarrow \textbf{1 mark}$$

$$T = \frac{2E_k}{3k}$$

$$= \frac{2(6.40 \times 10^{-21})}{3(1.38 \times 10^{-23})} \qquad \leftarrow \textbf{1 mark}$$

$$T = 309 \text{ K} \qquad \leftarrow \textbf{1 mark}$$

Note to markers:

Using $k = 9.0 \times 10^9$ $-\frac{1}{2}$ **mark**

Mixing K $\leftrightarrow$ °C $-\frac{1}{2}$ **mark**

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2. Air is travelling past an aircraft wing such that the speed is 42 m/s over the top surface
   and 32 m/s past the bottom surface. What is the difference in pressure for the two surfaces
   of this wing?   **(4 marks)**

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2 \qquad \leftarrow \textbf{1 mark}$$

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2 \qquad \leftarrow \textbf{1 mark} \quad \text{(Acknowledging } h_1 \doteq h_2 \text{)}$$

$$\Delta P = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$$

$$= \frac{1}{2}(1.29)(42^2 - 32^2) \quad \leftarrow \textbf{1 mark}$$

$$= 480 \text{ Pa} \qquad \leftarrow \textbf{1 mark}$$

Note to markers:

$\rho = 1.01 \times 10^5$ $-\frac{1}{2}$ **mark**

$\rho = 1\,000$ $-\frac{1}{2}$ **mark**

No work shown, but correct answer

$-1\frac{1}{2}$ **marks**

3. A block of ice floats on fresh water. What minimum volume must the block of ice have in order for a 73 kg man to be able to stand on it without submerging the block? The density of ice is 9.2×10^2 kg/m^3. **(5 marks)**

$$F_B = F_{g_{ICE}} + F_{g_{MAN}}$$ $\leftarrow$ $\frac{1}{2}$ **mark**

$$\rho_w V_w g = \rho_I V_I g + mg$$ $\leftarrow$ **1$\frac{1}{2}$ marks**

$\boxed{V_w = V_I}$
Same value **1 mark**

$$1\ 000(V)(9.8) = (920)(V)(9.8) + (73)(9.8)$$ $\leftarrow$ **1 mark**

$$80\ V = 73$$

$$V = 0.92 \text{ m}^3 \text{ (number may be rounded up in this case)} \leftarrow \textbf{1 mark}$$

Note to markers:

No workings shown $-1\frac{1}{2}$ **marks**

$$V = \frac{m}{\rho} = \frac{73}{920} = 0.079 \text{ m}^3$$ **1 mark**

END OF SECTION II: Fluid Theory

SECTION III: AC Circuitry and Electronics

1. A capacitor connected across a potential difference of 16 V has a charge of 3.8×10^{-5} C. What is its capacitance? **(3 marks)**

$Q = CV$ ← **1 mark**

$C = \dfrac{Q}{V}$

$\quad = \dfrac{3.8 \times 10^{-5}\,\text{C}}{16\text{ V}}$ ← **1 mark**

$\quad = 2.4 \times 10^{-6}$ F

$\quad = 2.4\ \mu\text{F}$ ← **1 mark**

$[C] = \dfrac{C}{V}$ okay

$Q = CV \ \rightarrow \quad\quad 6.1 \times 10^{-4} \quad\quad \mathbf{1\frac{1}{2}}$ **marks**
$\quad\quad\quad\quad \uparrow\ 3.8 \times 10^{-5}$ C
$\uparrow$
" capacitance"

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2. The graph below shows the current-voltage characteristics for a certain diode.
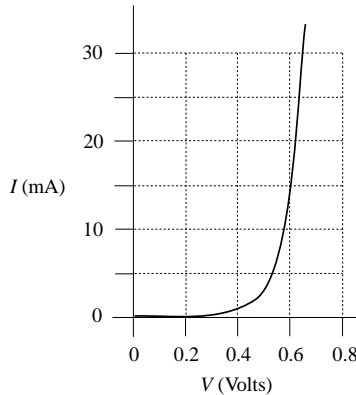
The diode is to conduct 15 mA when connected to a 9.0 V source. What resistance must be connected in series with the diode? **(4 marks)**

From graph: at 15 mA, $V = 0.60$ V   ← **1 mark**

$\therefore V_{drop} = 9.0\text{ V} - 0.60\text{ V}$

$\quad\quad\quad = 8.4$ V   ← **1 mark**

$\therefore R = \dfrac{V_{drop}}{I}$

$\quad\quad = \dfrac{8.4\text{ V}}{0.015\text{ A}}$ ← **1 mark**

$\quad\quad = 560\ \Omega$ ← **1 mark**
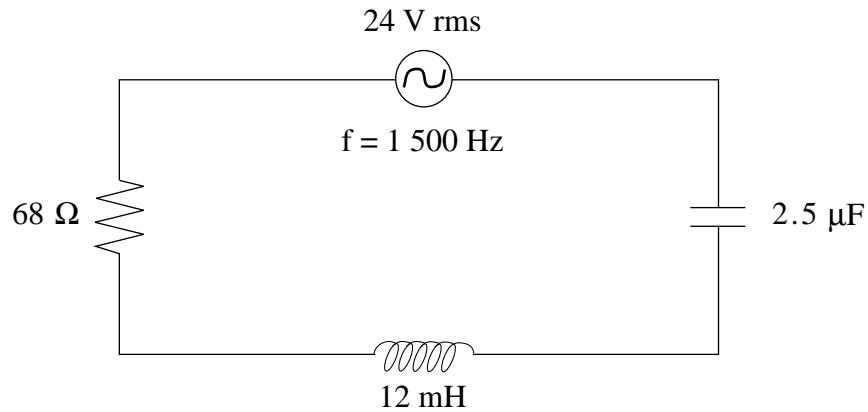
$\quad\quad = 5.6 \times 10^{2}\ \Omega$

Note to markers:

$R = \dfrac{V}{I} = 600\ \Omega$ $\frac{1}{2}$ **marks**

$R = \dfrac{0.60}{15 \times 10^{-3}} = 40\ \Omega$ $\mathbf{1\frac{1}{2}}$ **marks**

3. What is the voltage drop across the inductor in the circuit below? **(5 marks)**

24 V rms

f = 1 500 Hz

68 Ω

2.5 µF

12 mH

$X_C = \dfrac{1}{2\pi f C}$ $\left.\begin{array}{l}\\[1.5em]\end{array}\right\}$ **1 mark**

$\quad = 42.4\ \Omega$

$X_L = 2\pi f L$ $\left.\begin{array}{l}\\[1.5em]\end{array}\right\}$ **1 mark**

$\quad = 113\ \Omega$

$Z = \left(R^2 + \left(X_L - X_C\right)^2\right)^{\frac{1}{2}}$ ← **1 mark**

$\quad = 98\ \Omega$

$I = \dfrac{24\ V}{98\ \Omega} = 0.245\ A$ ← **1 mark**

$V_L = I X_L$ ← **1 mark**

$\quad = 28\ V$

END OF SECTION III: AC Circuitry and Electronics

END OF KEY